The Exposure Pyramid Framework and its Application to a Cross-Sectional Study of Lung Function

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Outline

- Introduction

- the Exposure Pyramid Framework

- Case study:
  Cross-sectional study of exposure to indoor air pollution (IAP) and lung function in India

- Conclusions

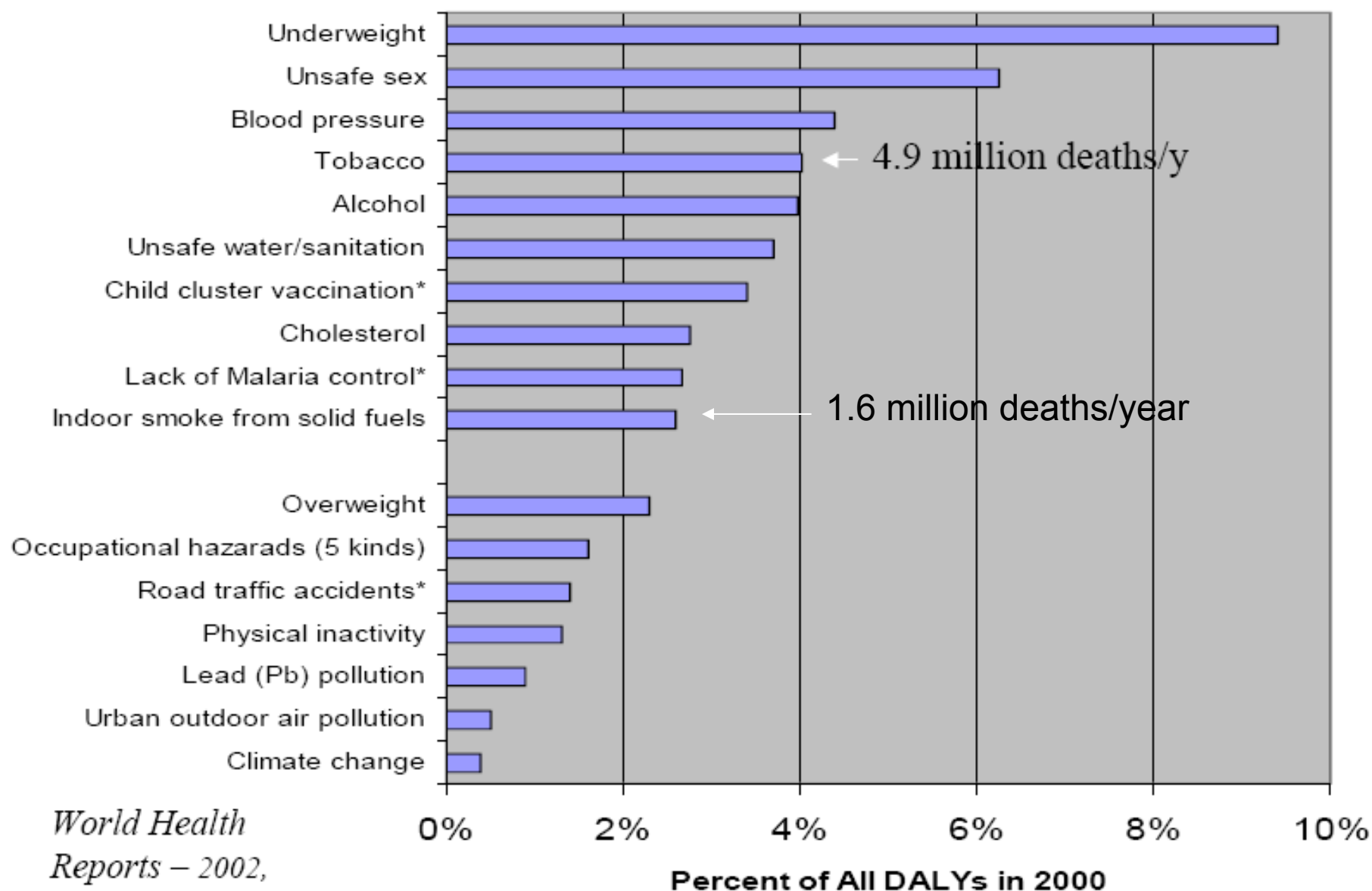# Why is IAP from solid fuels problematic?

- 50% of the world's population relies on solid fuels

- Exposure to IAP from solid fuels is strongly associated with ARI, COPD, & lung cancer

- 1.5 to 2 million deaths annually

Source: Smith K, Mehta S, et al. (2004). Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors.
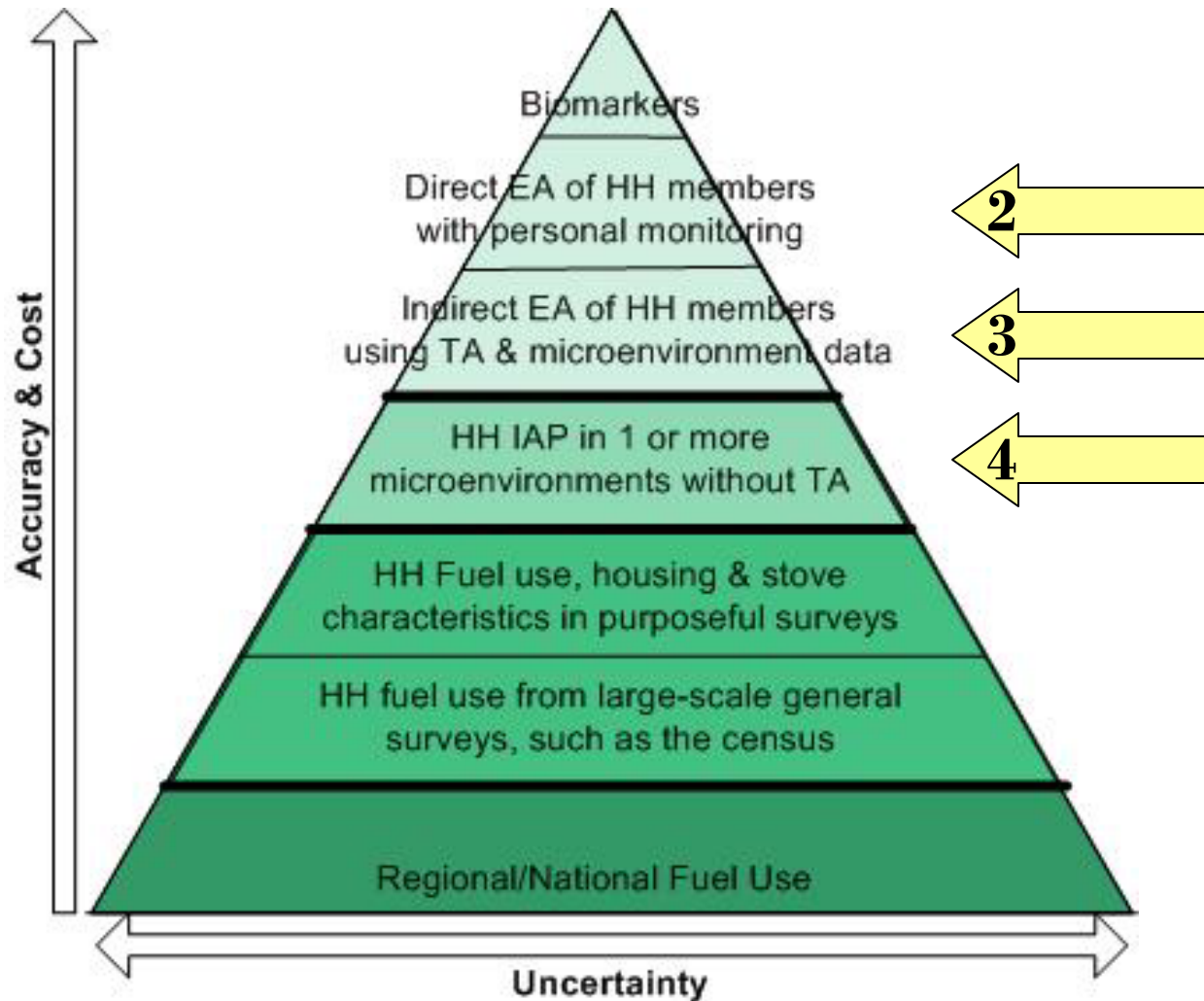

Chullah, traditional Indian stove in Uttaranchal, India

Global Burden of Disease from Top 10 Risk Factors
plus selected other risk factors

Risk Factor	Percent of All DALYs in 2000
Underweight	~9.4%
Unsafe sex	~6.2%
Blood pressure	~4.4%
Tobacco	~4.1% ← 4.9 million deaths/y
Alcohol	~4.0%
Unsafe water/sanitation	~3.7%
Child cluster vaccination*	~3.4%
Cholesterol	~2.8%
Lack of Malaria control*	~2.7%
Indoor smoke from solid fuels	~2.6% ← 1.6 million deaths/year
Overweight	~2.3%
Occupational hazarads (5 kinds)	~1.6%
Road traffic accidents*	~1.4%
Physical inactivity	~1.3%
Lead (Pb) pollution	~0.9%
Urban outdoor air pollution	~0.5%
Climate change	~0.4%

Percent of All DALYs in 2000

World Health Reports – 2002, 2001

The IAP Exposure Pyramid

Exposure Pyramid Research Aim

- Quantify the improvements, if any – in terms of accuracy – that result by shifting from indirect to direct methods in a 2-year CO exposure assessment of 64 rural women using wood fuel in highland Guatemala.
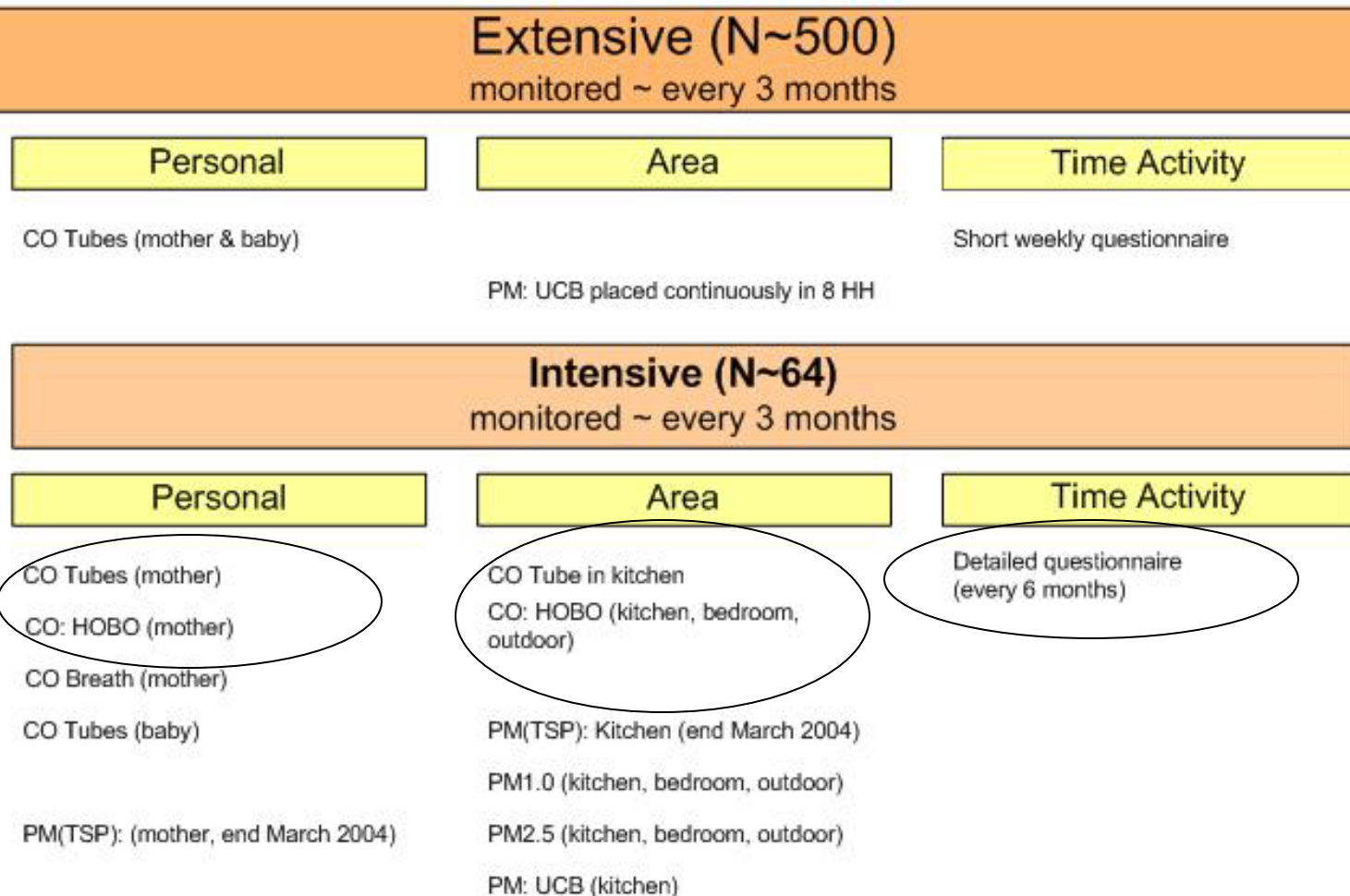
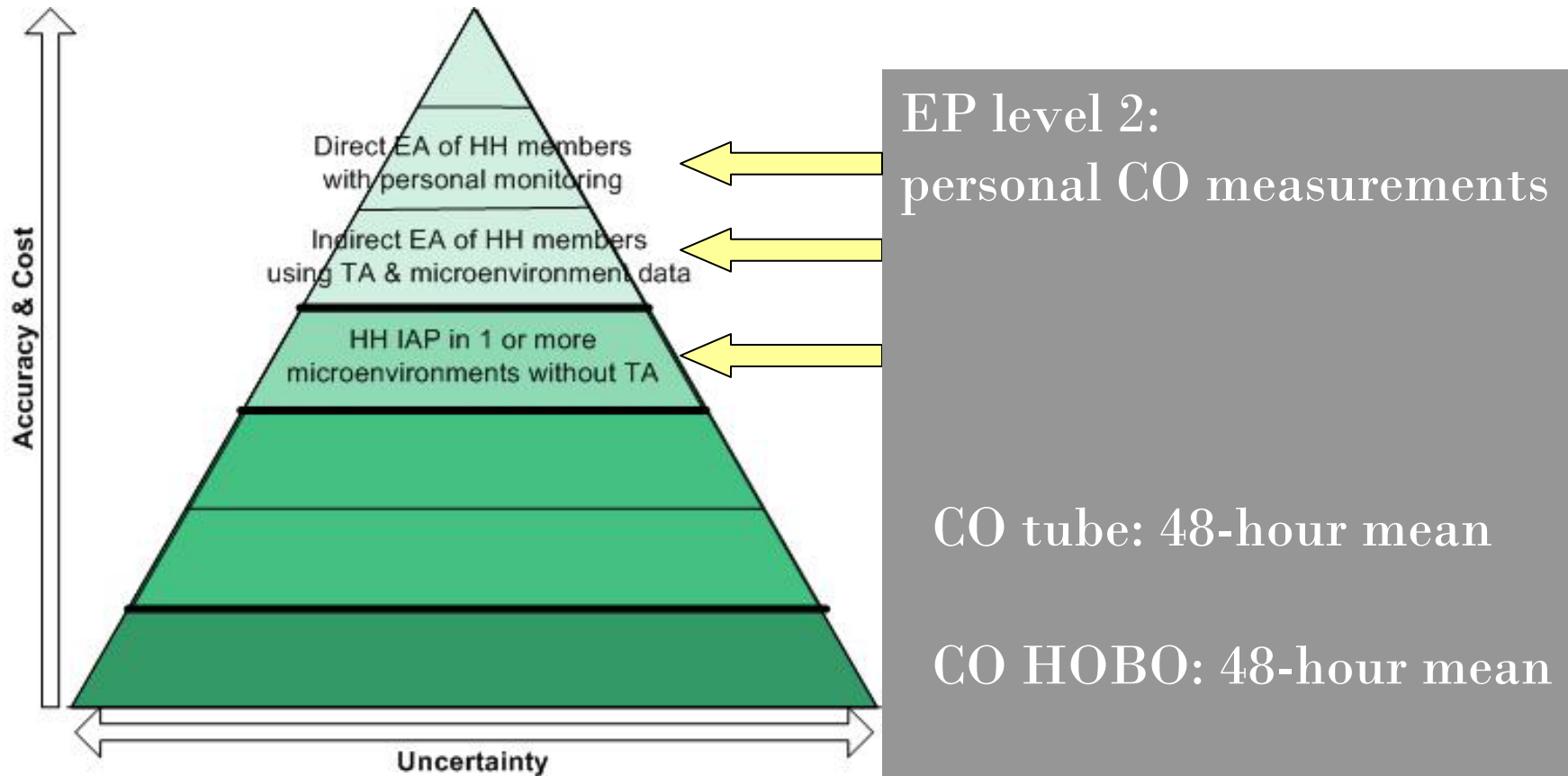# Study site (RESPIRE): Guatemala

plancha (improved stove)

RESPIRE IAP data

Dec 2002 – Dec 2004

Extensive (N~500)
monitored ~ every 3 months

Personal	Area	Time Activity
CO Tubes (mother & baby)		Short weekly questionnaire

PM: UCB placed continuously in 8 HH

Intensive (N~64)
monitored ~ every 3 months

Personal	Area	Time Activity
CO Tubes (mother)	CO Tube in kitchen	Detailed questionnaire (every 6 months)
CO: HOBO (mother)	CO: HOBO (kitchen, bedroom, outdoor)	
CO Breath (mother)		
CO Tubes (baby)	PM(TSP): Kitchen (end March 2004)	
	PM1.0 (kitchen, bedroom, outdoor)	
PM(TSP): (mother, end March 2004)	PM2.5 (kitchen, bedroom, outdoor)	
	PM: UCB (kitchen)	

Calculation of 64 Women's CO Exposures

(data source: CO tube and CO HOBO)

Direct EA of HH members with personal monitoring

Indirect EA of HH members using TA & microenvironment data

HH IAP in 1 or more microenvironments without TA

Accuracy & Cost

Uncertainty

EP level 2:
personal CO measurements

CO tube: 48-hour mean

CO HOBO: 48-hour mean

Methods to assess the relationship between metrics on each level of the Exposure Pyramid

- Least squares linear regression to calculate the coefficient of determination (R^2)

- Spearman's correlation coefficient

- Stepwise regression analysis to estimate personal CO measurements (including questionnaire data)

Correlations among Exposure Metrics at Different Levels of the Pyramid

Levels 2 and 4
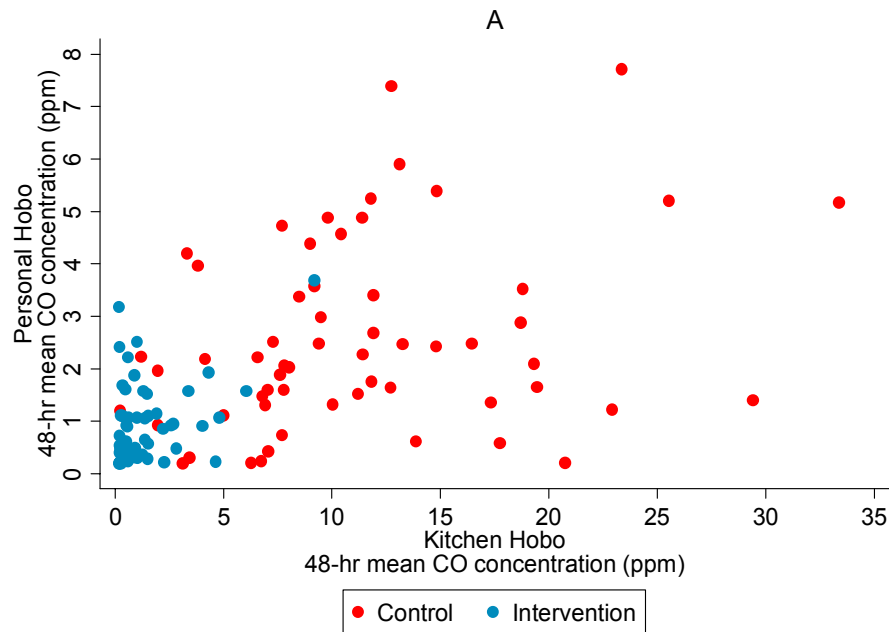
Level 4
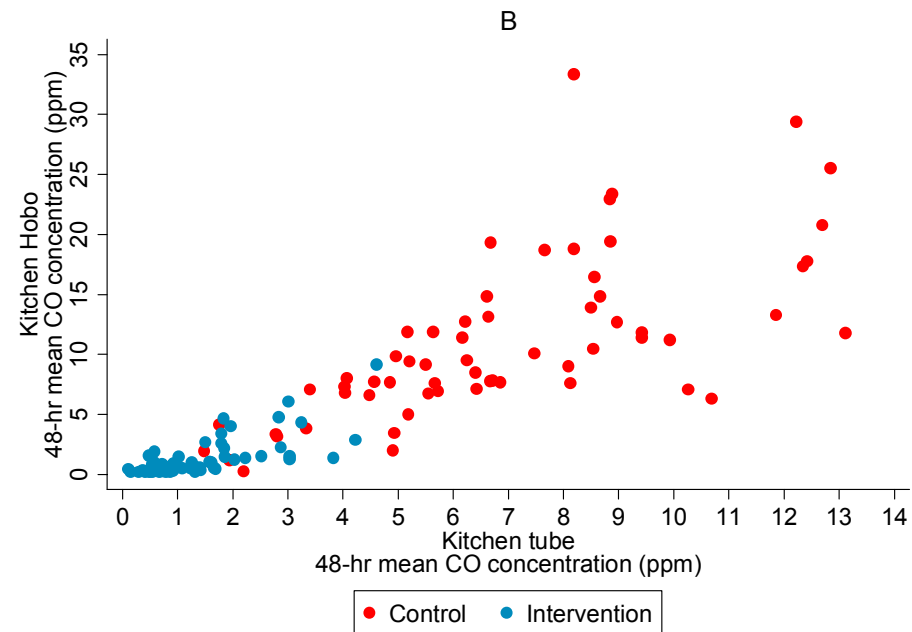
N=134
$R^2 = 0.28$

N=134
$R^2 = 0.74$

Results: Correlation Strength Between each Proxy and the Gold Standard
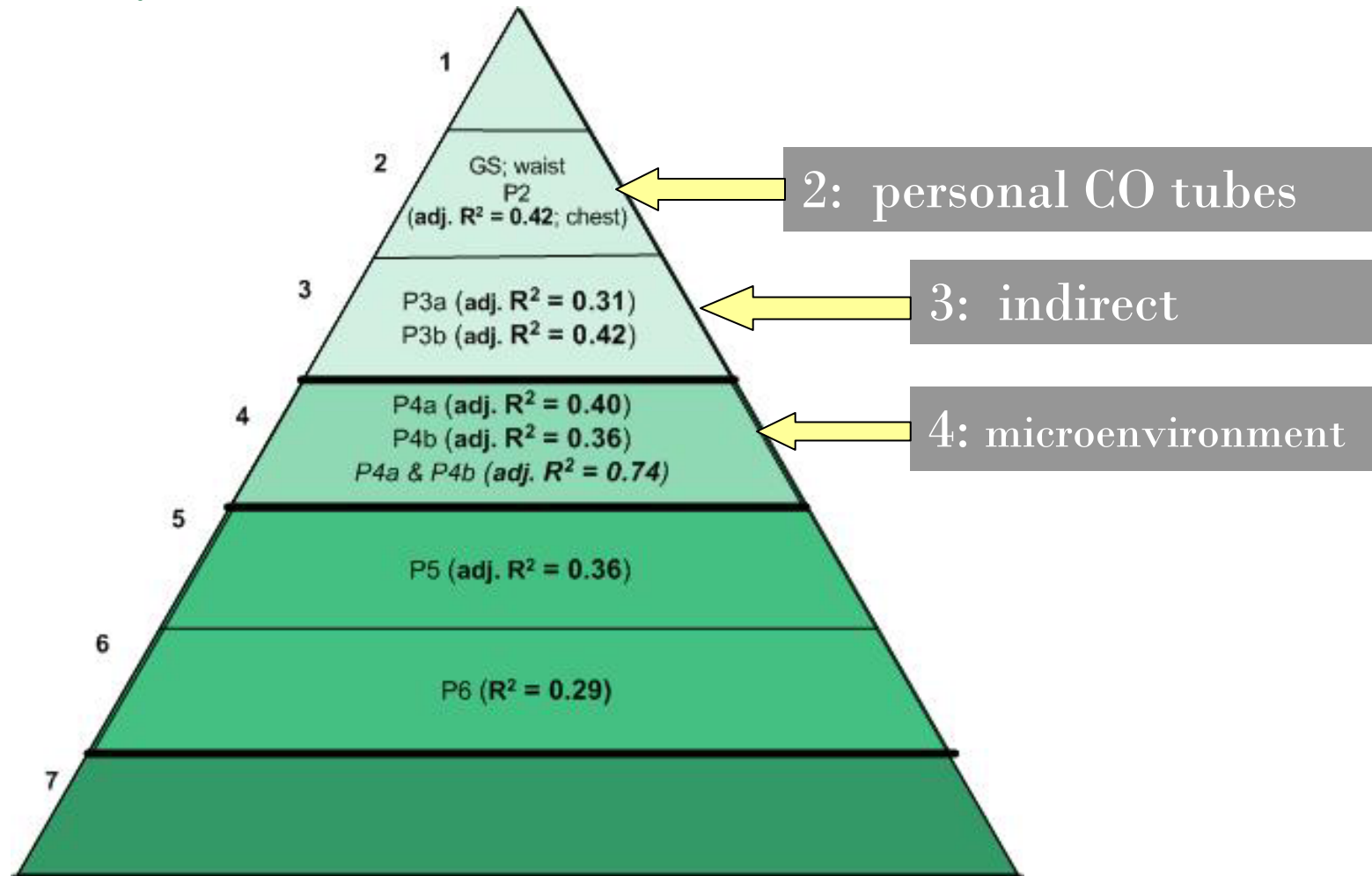
Results based on step-wise regression analysis.

Conclusions: Exposure Pyramid

- Correlation strength between the continuous personal CO measurements and simultaneously collected indirect and microenvironmental CO measurements ranged from adjusted $R^2 = 0.31 - 0.42$.

- Several factors may explain the lower than expected correlations, including instrument placement, inaccurate time activity data, HH ventilation patterns, and perhaps user error (results reported here are not atypical of similar results published in the literature).

- Analysis provides further justification for using area measurements to estimate exposure in studies by non-research groups.

Case study: Cross-sectional study of exposure to IAP and lung function in India
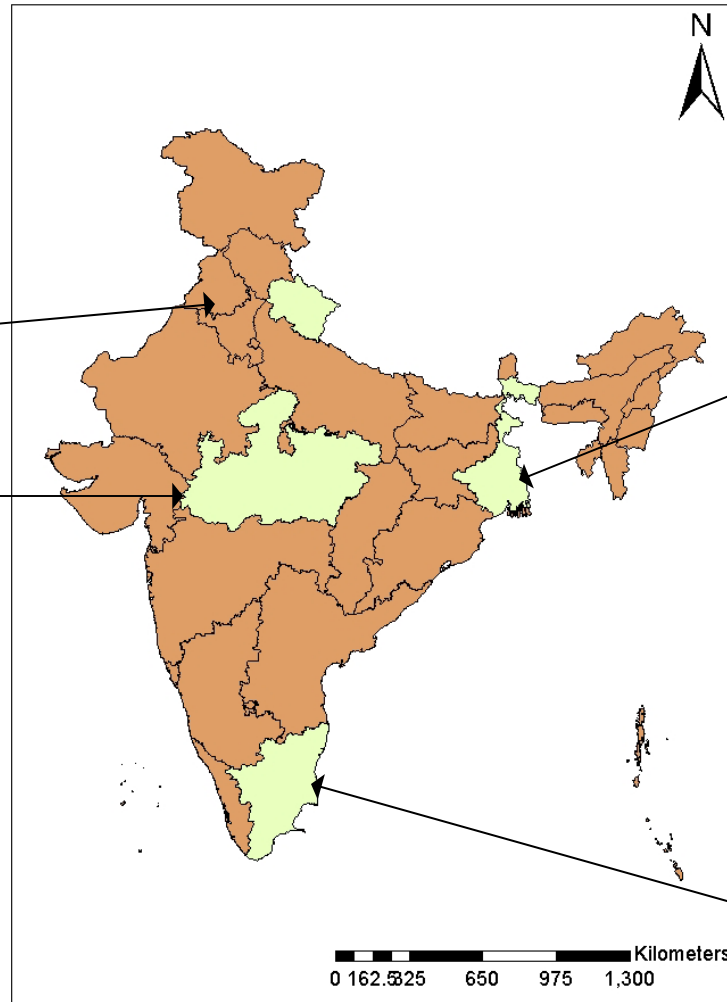
HEED Household Sampling Scheme
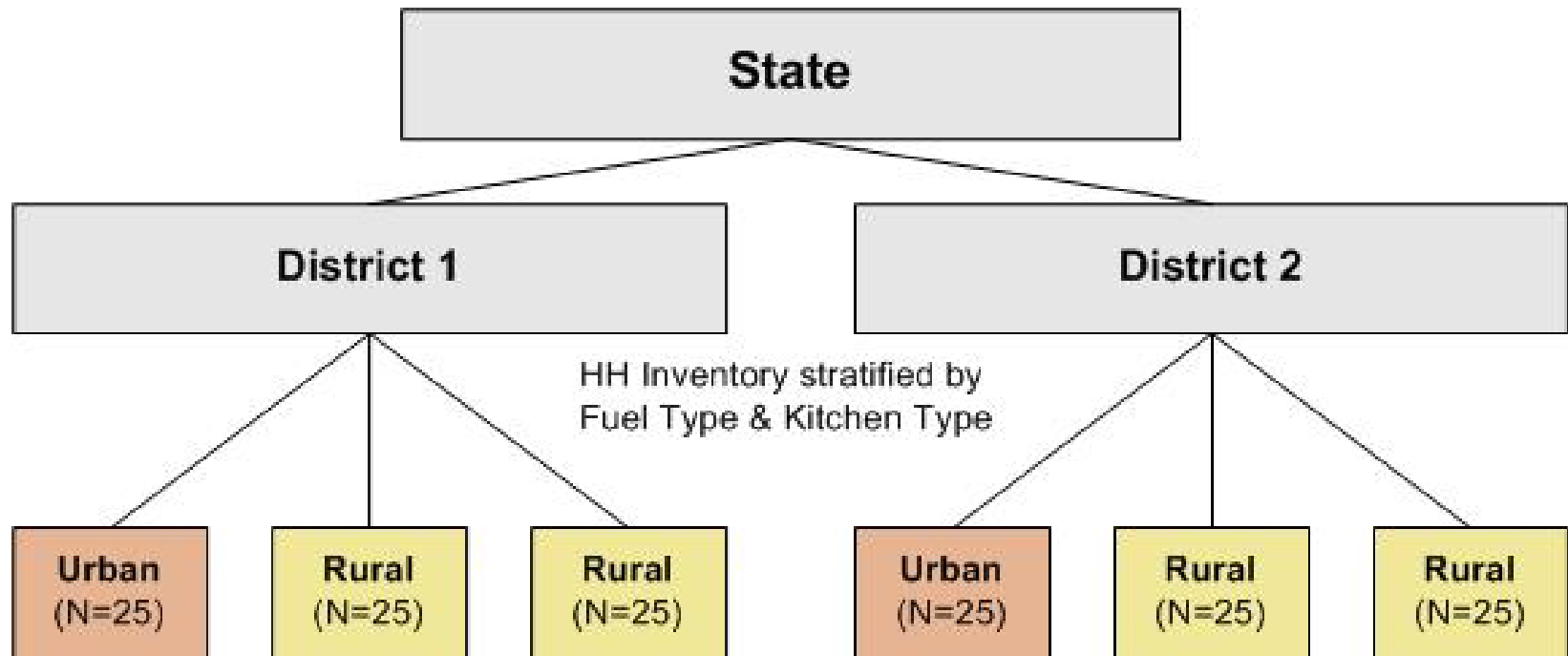
N = 150 households/state
N = 600 households total

HEED IAP data

(Nov 2004 – Feb 2005)

| HH1	HH2	HH3	HH4	HH5
Kitchen: UCB & CO tube Gravimetric Living: Grav & UCB Outside: some UCBs & Grav	Kitchen: UCB & CO tube Living: UCB Outside: some UCBs	Kitchen: UCB & CO tube Living: UCB Outside: some UCBs	Kitchen: UCB & CO tube Living: UCB Outside: some UCBs	Kitchen: UCB & CO tube Living: UCB Outside: some UCBs

Respiratory questionnaires and spirometry tests completed in all households; physician examination in Tamil Nadu.

Measuring Particles: Standard gravimetric (PM$_{2.5}$) and UCB particle monitor
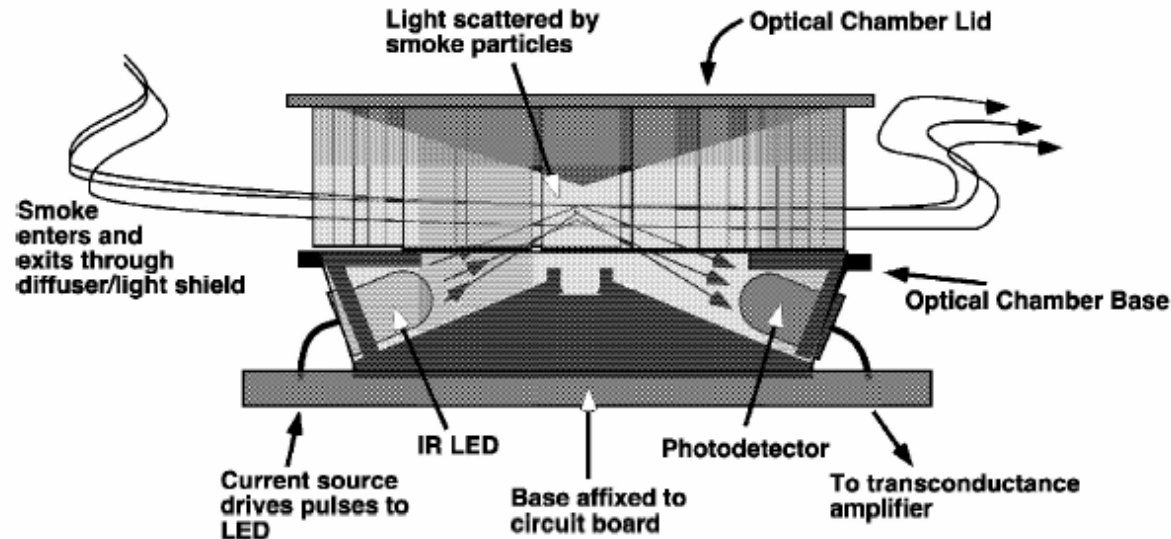
Sources
Chowdhury, Z., R. Edwards, et al. (2007). <u>Journal of Environmental Monitoring</u> [accepted 20 June 2007].
Edwards, R., K. R. Smith, et al. (2006). <u>J Air Waste Manag Assoc</u> 56(6): 789-99.
Litton, C. D., K. R. Smith, et al. (2004). <u>Aerosol science and technology</u> 38: 1054-1062.
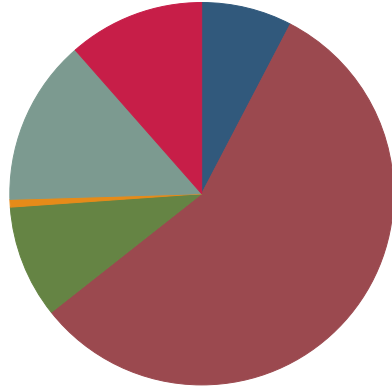
Typical Kitchen Concentrations in India
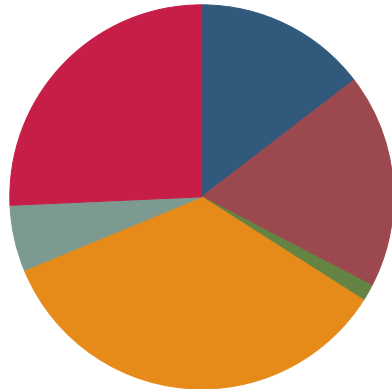
(all fuel/stove combinations)

Tamil Nadu, December 2004 to January 2005 (N=92)

WHO PM$_{2.5}$ 24-hr
guideline = 25 µg/m^3

$\bar{x} =$ 264 µg/m^3
SE(x) = 29.9 µg/m^3
median = 159 µg/m^3

47
20
8
5
3
2
3
3

Frequency

UCB Particle Montior PM2.5 22-hr kitchen concentration (ug/m3)
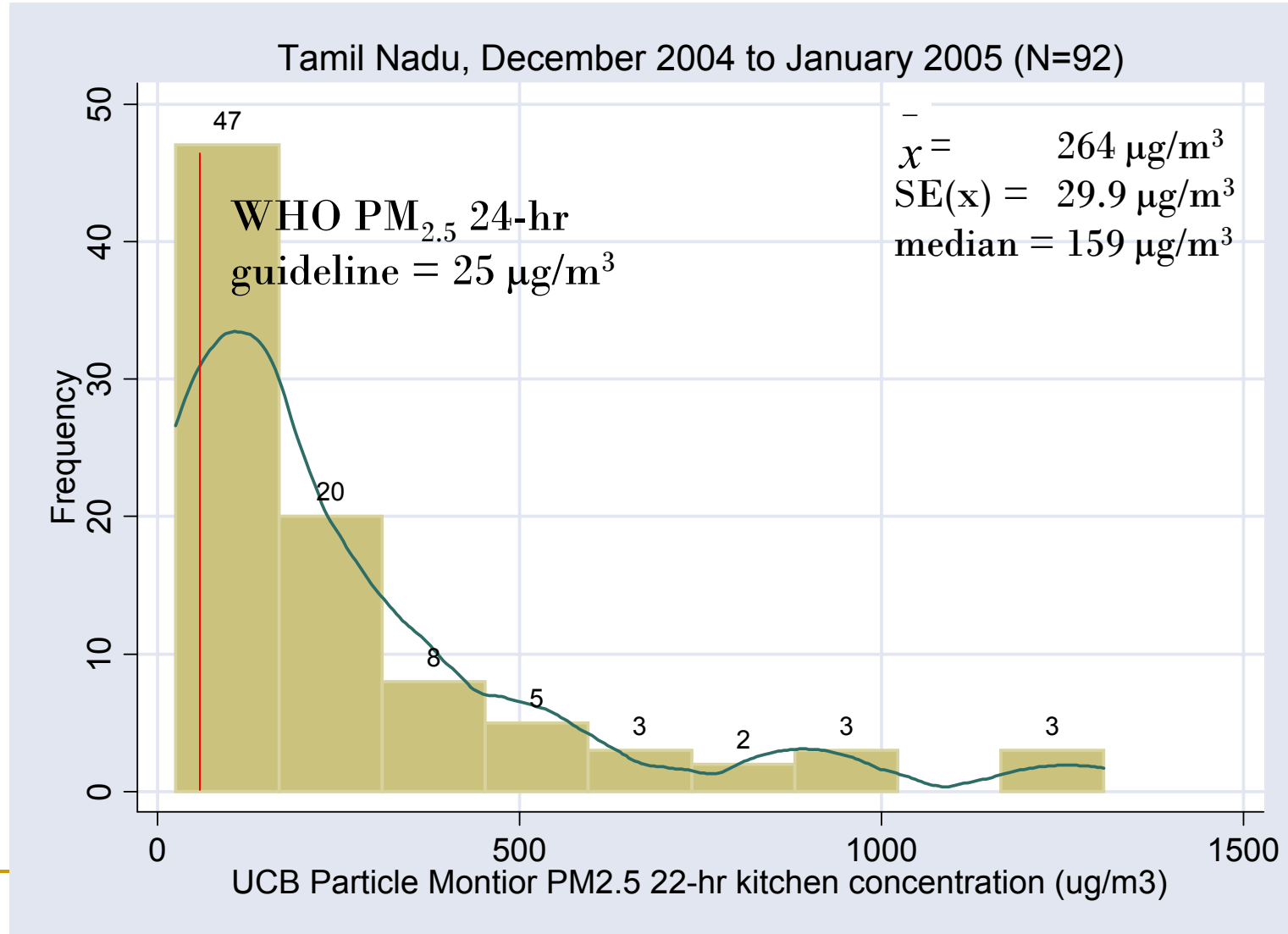
# Results, 1: Differences in housing types by state
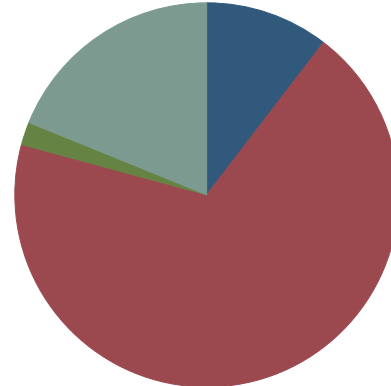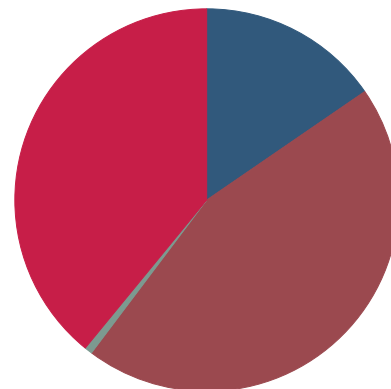
Results, 2: 24-hour PM and CO Concentrations
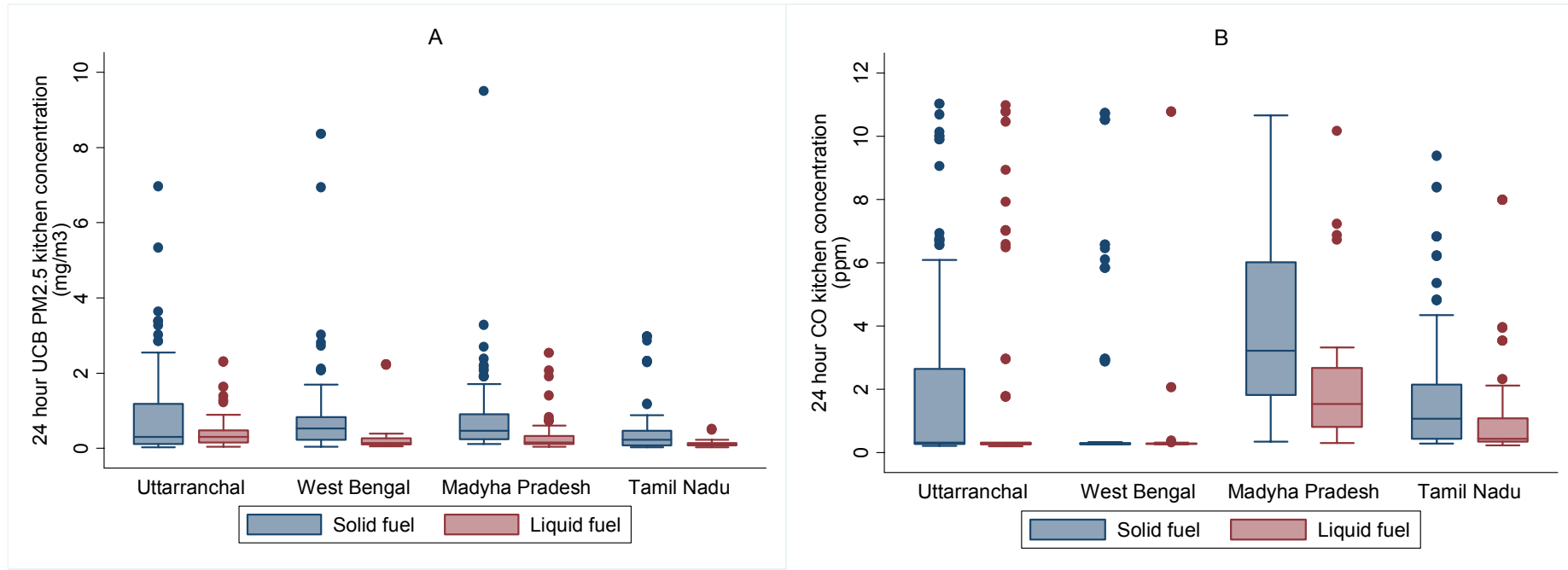
In all states, the mean 24-hour **PM$_{2.5}$ concentration** in clean-fuel-using HH was significantly lower than that in solid-fuel-using HH.

In MP and TN, the mean 24-hour **CO concentration** in clean-fuel-using HH was significantly lower than that in solid-fuel-using HH.

Spirometry tests in households in India
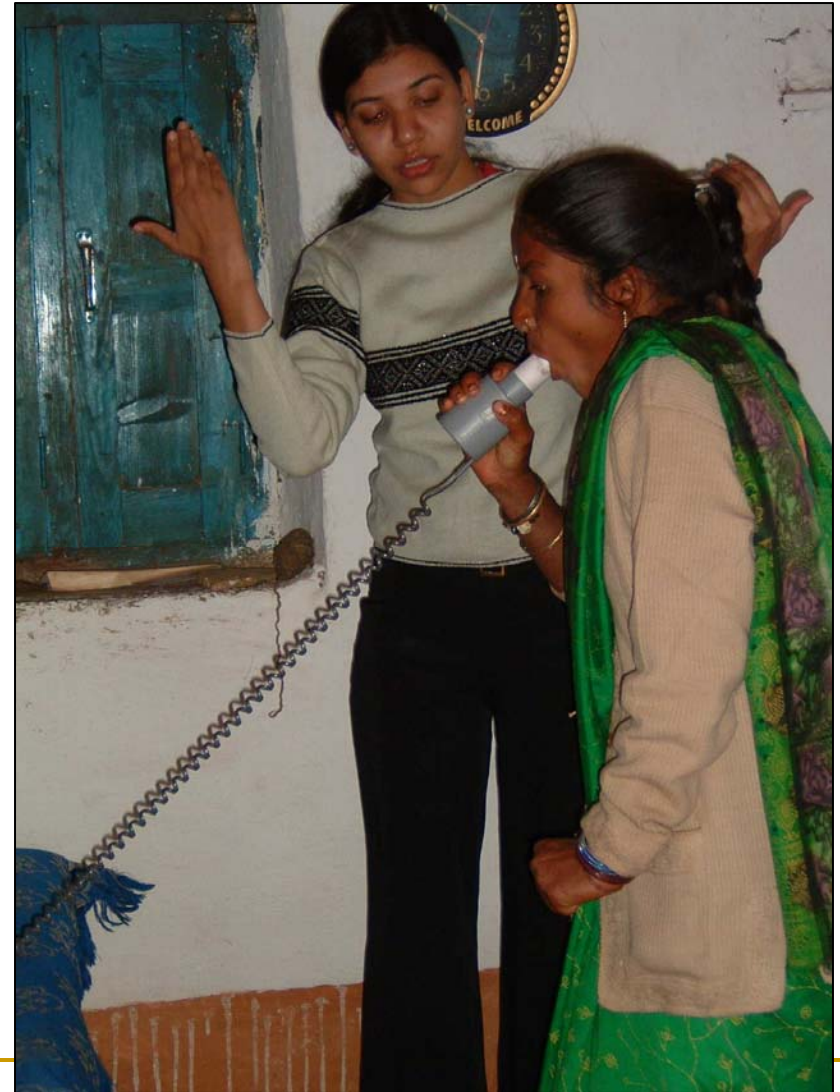
Results, 3: % predicted FEV$_1$ and FVC values by sex in solid- and clean-fuel-using households
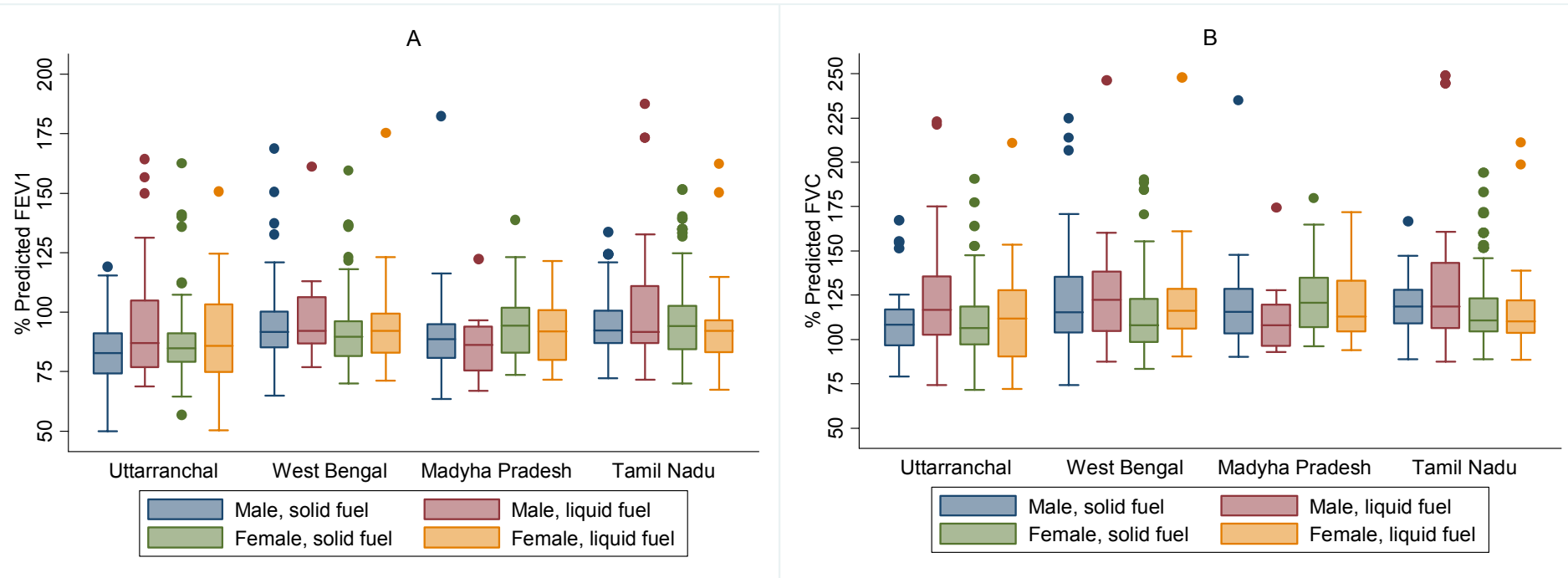
Among males, the mean % predicted FEV$_1$ and FVC were significantly higher among clean as compared to solid fuel users in Tamil Nadu.

The % predicted FEV$_1$ and FVC values differed significantly between males across the four states who lived in clean-fuel-using HH.

Conclusions: Case Study

- 24-hour mean kitchen concentration was 940 $\mu g/m^3$ in solid fuel households.

- 24-hour mean kitchen concentration was 290 $\mu g/m^3$ in clean fuel households.

- Values are 38 times and 12 times greater than the 2006 WHO Air Quality Guideline 24-hour mean $PM_{2.5}$ concentration of 25 $\mu g/m^3$.

- The strongest effects on lung function (FEV_1) in **women** were detected relative to peak concentrations of PM, i.e. age and height adjusted 24-hour 1-minute maximum $PM_{2.5}$ concentration (p=0.007) and adjusted 24-hour maximum 15 minute mean $PM_{2.5}$ concentration (p=0.042).

Implications and Research Plans

- Findings continue to support advocacy for the implementation, use and assessment of improved cookstoves as well as for better household ventilation.

- Currently investigating an approach for estimating reductions in ALRI and COPD mortality based on IAP measurements.

- Research plans:

  - Replicate the Exposure Pyramid analysis in a more controlled-setting where ventilation conditions and other factors can be more closely controlled.

  - Evaluate how other metrics – including using spatial analyses such as krigging and linear interpolation to create IAP "exposure surfaces" – fit into the Exposure Pyramid framework.

Acknowledgements

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